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Potential applications of wastes from energy generation particularly biochar in Malaysia

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ABSTRACT

In Malaysia, abundant agricultural wastes are generated yearly. Therefore it is beneficial to discover new ways to utilize the wastes and employ the carbon source in different industries. Biochar are produced through many heat treatments such as combustion, gasification and pyrolysis for energy generation. The characteristics of these stable carbons such as the physical properties, chemical composition, surface area and surface chemistry determine the effectiveness of the cabon in different applications. Biochar has the ability to retain carbon and this condition is advantageous to prevent the release of carbon back to the atmosphere in the form of carbon dioxide. Application of biochar to soil helps to improve soil fertility and raise agricultural productivity. Biochar also has the ability to reduce carbon dioxide in the flue gas system. There have only been a few studies that discuss on the potential applications of this agriculture waste. The biochar's potential application as carbon sequester for soil application, energy production and dye sorption is being explored in this paper.

Contents

1. Biochar potential application

The increase of carbon dioxide in the atmosphere has driven a rapid rise in global temperature which resulted to the shift of weather patterns. The large imbalance between carbon release to the atmosphere and carbon uptake by other compartments leads to rapid growth of CO_2 emissions to 8.4 billion tons in 2009 [3]. The implementation of Kyoto protocol was foreseen to improve the climate change by execution of environmental policy and improving Clean Development Mechanism which allows countries to meet their obligations by helping developing countries in clean energy projects. Strict technical standards and rules were employed for the energy efficiency of buildings and vehicles. Incentives were also provided to encourage power companies to develop greenhouse gas efficient technologies. Supports were provided to improve the cost efficiency of carbon capture and storage technologies. Nevertheless these efforts were found to be ineffective in reducing the greenhouse gas emissions. Other than energy efficiency measures, it is important to develop new methods to maintain carbon in a stable form that can be stored

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outside the atmosphere for longer periods. One promising approach to lowering CO_2 in the atmosphere is by utilization of biochar.

Biomass utilization for energy generation is an interesting field to be discovered to produce efficient energy. Malaysia has an abundant biomass waste such as rise husk, palm kernel, coconut shell, empty fruit bunch, sawdust and bagasse that can be utilized to generate energy. Each year the biomass residues increases and extensive studies have been performed to discover potential use of the waste. In Malaysia's palm oil plantation areas, more than 66.63 million tones of biomass residues produced in 2010 such as shell, palm kernel, empty fruit bunch, fronds and trunks. These oil palm residues have the potential to be used as a renewable energy resource [1]. Power can be generated by various thermal treatments such as pyrolysis, gasification and combustion [2]. Energy and bio oil will be produced during these thermal treatments together with biochar as residues. Biochar is a carbon rich product that remains when biomasses are pyrolyzed in a closed container. Previously biochar are used in the construction field in which the biochar are mixed in different ratios to produce bricks or blocks. Extensive studies have shown that the biochar has potential values to be incorporated in soil as carbon sequesters to preserve the environment. It is also used as carbon dioxide adsorbent in flue gas during energy production and as dye removal in the waste water industry.

In addition biochar has the potential to remove dyes in the waste water industry. The removal of dyes from waste effluents is environmentally important as the dye is very harmful and toxic [4]. Various types of dyes such as red and methylene blue dye are frequently used in the fabrics industry to dye cottons, silks and sheets. The substance is hazardous as it can cause eye burns and short period of breathing difficulty if inhaled continuously [5]. The utilization of biochar as an adsorbent is foresee to be a big advantage as it is a biowaste material and has low cost.

In this paper, applications of the biochar are being discussed in various fields to complement the huge amount of agricultural wastes in Malaysia. Issues that can further be studied in each field are also being discussed to improve the effectiveness of the biochar application. The availability of biomass is also included to verify the great potential of biochar to be produced in Malaysia that can be engaged in diverse industries.

2. Capture and green house gasses (GHG) sequestration

The emission of excessive carbon dioxide in the atmosphere has contributed to serious global warming. The strategy to combine the pyrolysis process is being applied by taking advantage of the biochar produced from the process to be used as soil fertilizer. The process cycle has the ability to be carbon negative whereby carbon dioxide will be removed from the atmosphere while energy is being generated. The advantage of biochar addition to soil is that it has the ability to retain nutrients, high stability against decay, able to remove carbon dioxide from the atmosphere and revitalize degraded grounds. The sequestration capacity and the carbon retained in biochar depend on the production temperature, type of biomass, soil conditions and weather changes [6]. Different char has different chemical structure and functional groups. It is believed that the carbon–oxygen complexes content increases the adsorption capacity of the biochar [7].

Soils have the ability to retain nutrients depending on the amount of soil organic matter. The same goes for biochar whereby it has great capacity to adsorb cation per unit carbon since it has high surface area, high negative surface charges and greater charge density. Although biochar will in time decay and release carbon dioxide, the phase of decomposition takes a very long time compared to other organic carbon in soil [8]. Table 1 shows the summary of the advantages of biochar addition to soil and the current issues on the study of biochar that needs to be studied in depth.

The application of black carbon to soil with addition of fertilizers can increase the crop yield. In the study of wheat growth by Zwieten, the effect of biochar alone does not give significant effect of biomass yield. Combination of biochar with fertilizers however gives varies responses of increased soybean biomass but reduced wheat and radish biomass [9].

Until now the effects of carbon dioxide increment from soil is still in study as it involves many bases. The elevation of CO_2 is still unclear as there are constraints depending on the chemistry of the soil and the experimental set up. Some of the boundaries are the limiting nutrients, amount of C in soil, soil acidity, microbial activity, and amount of phosphorus and potassium in fertilizers. Open-top chambers were installed to evaluate the release of CO_2 on soils by Johnson, Hungate, Dijkstra, Hymus and Drake. Carbon dioxide concentration were taken monthly from the gas wells and analyzed using gas analyzers. However the hypothesis of the experiment in which the elevated CO_2 would increase the soil respiration could not be proven. It is believed the large amount of live root biomass that survived the slash and burn activity remained and therefore causing treatment effects on living root biomass or root activities. Further studies are needed to understand the respiration system of the soil in order to have better understanding on the CO_2 flux to the atmosphere [10].

Study on the biochar application in loamy soil shows that the highest biochar carbon sequestration was achieved by char pyrolyzed at 500 °C with overall carbon mitigation of 380 g/kg C although it is believed that char produced at high temperature is more recalcitrant than low temperature. The lowest carbon mitigation is from 575 °C char with 280 g/kg C. The highest CO_2 emission comes from the low temperature treated biochar. After 115 days incubation, the carbon loss ranged from 11.9% for 475 °C char to 3.1% C loss for 575 °C char [11]. Table 2 shows a summary of few studies on the evaluation of carbon emission and the effects of the biochar application.

Another study on the effects of biochar-amended soils in an incubation system by Zimmerman et al. has shown that bochar-C losses of 3–30 mg C/g biochar. year. Biochar made at lower temperature degrade faster than high temperature char. Char made from grasses degrade faster than woods. Therefore the total degraded biochar C was directly related to the volatile content of the biochar. CO_2 from mixture was always less than soil alone where CO_2 sequestration happens. It is examined that 10–13% of C was lost from each soil/year while soil–biochar mix lost 1.2–9.5% C [13].

Application of char added in soil by Roger et al. shows that after the duration of biochar testing for 15 months, the amount of char in the added soil does not change much compared to initial char added to soil. It can be said here that biochar is a stable component and able to remain in soil for years [14]. Wheat straw char produced by pyrolysis gives promising results whereby the highest CO_2 sequestration is achieved at 500 °C char at 380 g/kg C and the lowest is from 575 °C char at 280 g/kg C after 115 days. However biochar produced at lower temperature produces highest CO_2 emission. This is because of the microbial decomposition of easy degradable fraction of biochar. After the week, the CO_2 emission stabilized to the same level as the reference soil [11].

Most studies conducted were performed in an incubation system to obtain a controlled system. Different types of biochar give varying carbon sequestration results. Further studies on the properties, pore sizes and surface area of the biochar may give clearer grounds on its ability to sequester carbon and the

Table 1
Advantages of biochar addition to soil and issues on the study of biochar.

Advantages of biochar addition to soil	Issues on the study of biochar
A carbon negative process whereby CO_2 will be removed from the atmosphere while energy is being generated [6]. Has the ability to retain nutrients and high stability against decay. Although biochar will in time decay and release carbon dioxide, the phase of decomposition takes a very long time compared to other organic carbon in soil [6].	Combination of biochar with fertilizers is needed to see the effects of agriculture yield [9]. The elevation of CO_2 is still uncertain as there are limitation depending on the chemistry of the soil and the set up of the experiment [10].
Different char has different chemical structure and functional groups. It is believed that the carbon–oxygen complexes content increases the adsorption capacity of the biochar [7].	The problems with biochar are the limiting nutrients, amount of C in soil, soil acidity, microbial activity, and amount of NPK in fertilizers [10].
The sequestration capacity and the carbon retained in biochar depend on the production temperature, type of biomass, soil conditions and weather changes [6].	Direct estimations of black carbon decomposition rates are not available and unclear because the black carbon content changes are too small for any relevant experimental period. Estimation on CO_2 flux is also unsuitable because the adsorption is too small compared to soil organic matter [12].
Great capacity to adsorb cation per unit carbon since it has high surface area and able to revitalize degraded grounds (soils) [6].	Microbial decomposition varies according to types of biochar where decomposition occurs depending on the degradable fractions of the biochar [11].
	An incubation study by adding external energy source (glucose) gives no changes to the total CO_2 flux. Assumption: If char decomposes 10 times slower under natural condition, the mean residence time will be 2000 years. Long time to study the effects of CO_2 flux [12].

Table 2
Summary on the effects of the biochar application and the evaluation of carbon emission.

Field/Biochar	Experimental set up	Results	Duration
Woods and grass (Combusted at 250 and pyrolyzed at 400, 525 and 650 °C) [13].	Incubation Process: Microbial insulate and NPK were added. Oxidation of char was taken monthly using CO_2 coulometer.	• Biochar-C losses of 3–30 mg C/g biochar. Year. • The degradation of biochar produced at low temperature is faster. Char from grasses degrade faster than woods. Soil C mineralization rate is 0.8–6.4 mg C/g biochar. Year. • CO_2 from mixture was always less than soil alone (CO_2 sequestration happens) 0.10–13% of C was lost from each soil/year. Soil–biochar mix lost 1.2–9.5% C.	500 days (Normalized as 1 year)
Addition of hardwood to formerly planted corn soil [14].	Loss and ignition Process: Thermally oxidized char via slow pyrolysis.	• No significant effect of the 15 months residence time of biochar in the field soil. • Amount of char in the added soil does not change much compared to initial char inserted.	15 months
No biochar added. Study conducted at Soybean field at Uni. Of Nebraska [15].	Chamber based Process: Usage of CO_2 Automated Flux System in a 20 cm chamber	• The CO_2 flux shows a strong diurnal (active during daytime) pattern subsequent to variation of soil temperature. Microbial respiration increases as temperature increases. • Normally the soil CO_2 flux is from 1–10 μmol/m^{2}s^1 depending on soil temp, moisture, organic matter and weather.	–
16 biochar added to 3 soils (agricultural, forest nursery and landfill cover) [16].	Incubations: Triplet incubations were prepared for each biochar. Soil+biochar were inserted inside serum bottle.	• All chars show CO_2 production or release however turkey manure+woodchip char adsorb CO_2 whereby within 5 days CO_2 was not detectable. • In soil+biochar incubation, only wood pellets stimulated CO_2 respiration across all soils. This is related to the biochar produced at limited aerobic environment (with air) and may have high oxygen contents.	100 days
Wheat straw char sample undergoes fast pyrolysis at temperature: 475, 500, 525, 550 and 575 °C [11].	Incubation system and infrared gas analysis to study CO_2 emission.	• All biochar emit large CO_2 emission during 1st week of experiment, 9–11 mg CO_2–C/g soil day. (Microbial decomposition of easy degradable fraction of biochar). After the week, the CO_2 emission stabilized to the same level as the reference soil. • The highest CO_2 emission comes from the low temperature treated biochar. Range after 115 days: C loss from 11.9% for 475 °C char to 3.1% C loss for 575 °C char. • Highest CO_2 sequestration is achieved at 500 °C char (380 g/kg C). Lowest is from 575 °C char (280 g/kg C).	115 days

effectiveness of biochar application to soil in order to implement carbon mitigation strategy.

3. CO_2 emission reduction in fuel application and energy production

There are a few methods that can be applied to reduce carbon dioxide emission to the atmosphere. Efforts can be made to improve the efficiency of energy production, reduce the carbon content of fuels and sequester carbon dioxide in the flue gasses. Carbon dioxide is produced by the fossil fuel combustion process that is used in energy production [17]. Currently the carbon dioxide is being sequestered by amine scrubbing of the flue gasses. This chemical absorption method is performed by using monoethanolamine (MEA) solvent which reacts with the flue gasses and is then mixed in the absorber. The carbon dioxide rich solution is sent to the stripper and reheated to separate almost pure carbon dioxide which is useful for industrial process. However this process is not economic as it needs large equipment sizes and high regeneration energy requirements.

Other than using MEA chemical absorption, membrane technology is also applied to facilitate the carbon dioxide absorption. During the separation of CO_2 with the flue gas, the mass transfer area is increased to help accelerate the scrubbing process. However amine is still used in this technology to separate CO_2 from the flue gas which can cause corrosion to the membrane eventually be destroy the equipment [18].

Thus, it is important to develop new methods to maintain carbon in a stable form that can be stored outside the atmosphere for longer periods. Several methods such as the utilization of porous carbon [19], membranes [20,21], zeolites [22,23], silica gel [24], aqueous solution [25,26]. The chemical incorporation of basis and acid alters the properties of carbon and therefore modifies the capability of the adsorbent to adsorb CO_2. One promising approach to lowering CO_2 in the atmosphere is by utilization of biochar.

Activated carbon is effective to sequester CO_2 as it has high adsorption capacity at ambient pressure, can be regenerated and it does not require moisture removal. The adsorption capacity depends on the surface chemistry and texture. Incorporation of nitrogen functionalities in the carbon structure can enhance the adsorption of the CO_2. The nitrogen functionalities can be introduced by treatment with ammonia, amine or acid [27].

One well-known recommendation to improve adsorption capacities of char is by filling N with amine compounds incorporated to the carbon structure. A study on CO_2 capture from high carbon fly ashes was conducted by Mercedes et al. Steam activation at 850 °C and amine treatment consisting of MEA, DEA and MDEA were performed for 20 min and dried in air at 120 °C. The adsorption capacity of activated fly ashes treated with amine gives higher adsorption capacity compared to previous study of only fly ashes amine treatment with adsorption of 68.6 versus 45 mg CO_2/g sorbent. As temperature increases for adsorption of CO_2, the contribution of physical adsorption decreases and equalizes any gain in the chemical adsorption of the loaded amine group. Chemically attached amino groups in fly ash derived sorbents may have great potential when used in flue gases for CO_2 capture [28]. CO_2 is an acid gas; alkaline surface functional groups will favor chemisorptions of CO_2. Some nitrogen groups are alkaline which are amine groups and imine groups [29]. Table 3 shows several treatments involving amine that affects the CO_2 adsorption capacity of the carbon.

Table 3
Amine treatments onto carbon.

Sample	Treatment	Raw BET surface area (m^2/g)	BET surface area after treatment (m^2/g)	CO_2 adsorption capacity mgCO_2/g adsorbent
Fly carbon [28]	Steam activation and amine treatment	75	MDEA: 204 DEA: 265 MEA: 241 MDEA+MEA: 302	**Temperature 30 °C** MDEA: 17.1 DEA: 21.1 MEA: 68.6 MDEA+MEA: 32.6 **Temperature 70 °C** MDEA: 30.4 DEA: 37.1 MEA: 49.8 MDEA+MEA: 35.8
Anthracites [29]	Steam activation, NH_3 heat treatment and polyethylenimine (PEI) impregnation	1000	NH_3: 1052 PEI: <1	**Temperature 75 °C** Raw: 16.05 Steam activation: 21.55 NH_3: 23.69 PEI: 26.30
Norit Activated Carbon [30]	Diethylentriamine (DETA), pentaethylenehexamine (PEHA) and polyethylenimine (PEI) impregnation	1762	DETA: 157 PEHA: 170 PEI: 90	**Temperature 25 °C** Raw: 21.3 DETA: 10.9 PEHA: 12.3 PEI: 13.1
Mesoporous Molecular Sieve [31]	Polyethylenimine (PEI) impregnation	–	–	**Temperature 50 °C** Raw: 14.3 PEI: 40
Commercial palm shell-based granular activated carbon [32]	Ammonia treatment and amination of oxidized sample.	768	889	**Temperature 30 °C** PEI: 73.5
Palm Shell Activated Carbon (AC) used to precursor carbon molecular basket [33]	Polyethylenimine (PEI) impregnation	941	1052	**Temperature 25 °C** Raw: 3.56 PEI: 3.26

Table 4
Adsorption capacity of different char samples on different sorption components.

Char samples	Treatments	Sorption components	Adsorption capacity (mg/g)	Reference
Coconut Shell char	NaOH-activated	Methylene blue	916.26	[53]
Willow-derived char	–	Perfluorooctane sulfonate (PFOS)	91.6	[54]
Maize straw char	–	Perfluorooctane sulfonate (PFOS)	164	[54]
Bagasse	Sulfuric acid and physical activation	Acid blue 80	384.6	[55]
Oil palm fiber	Chemical and physical activation	Methylene blue	277.78	[56]
Waste medium density fibreboard (MDF) sawdust	Chemical and physical activation	Red dye	14.47	[57]
Bone char	Chemical and physical activation	Reactive black 5	157	[58]
Rice straw char	Acid treatment	Malachite green oxalate	148.74	[59]
Sewage sludge derived chars	–	Basic blue 41	588	[60]

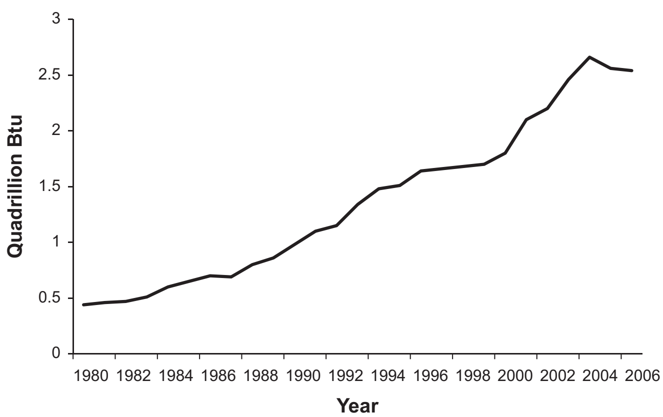

Fig. 1. Total primary energy consumption in Malaysia [62].

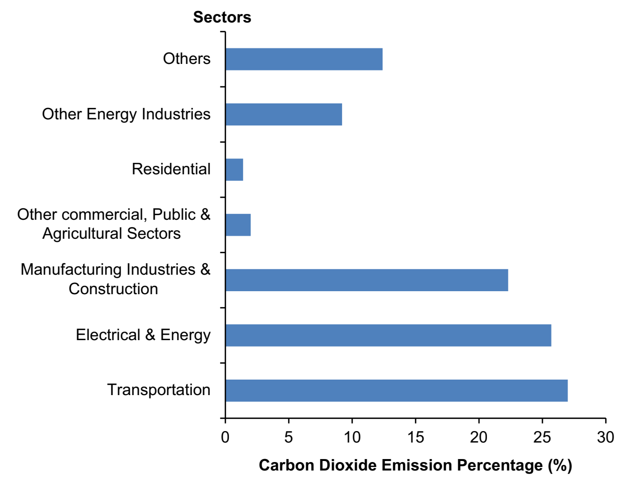

Fig. 2. Carbon dioxide emitted by various sectors in Malaysia [63].

4. Dyes sorption by utilizing biochar

Biochar are residues that formed during heat treatment process to produce energy. Alternatives to find environmental friendly applications are studied to utilize biochar rather than dumping them in the landfill. One of the applications that are currently being studied is the ability of the biochar to remove dyes in the waste water industry. The raw solid waste that is cheap and easily acquired has the potential to be used as adsorbent. Sorption experiments conducted for char collected from a thermal power plant has the adsorption capacity of 5.574 mg/g to remove methylene blue dye [36]. Other than that a study on char obtained from different boilers in Western Australia also shows that the sample has the ability to remove methylene blue with the adsorption capacity of 12.7 mg/g [37]. Table 4 shows the results of application of char to several types of dyes. Untreated willow and maize straw derived char gives an adsorption capacity of 91.6 and 164 mg/g of Perfluorooctane sulfonate (PFOS) [54]. Other treated char sample, such as bagasse gives higher adsorption value of 384.6 mg/g.

In Malaysia, an extensive study has been performed onto kenaf fiber char to evaluate the adsorption capacity onto methylene blue. It was observed that the treated kenaf char shows adsorption capacity of 18.18, 21.74 and 22.73 mg/g at 30, 40 and 50 °C respectively [34]. For that reason it can be said that the biochar has the ability to remove methylene blue in the waste water industry. The adsorption capacity may increase tremendously by chemical activation such as impregnation of potassium hydroxide [38–40], zinc chloride [41–43], NaOH [44–46], phosphoric acid [47–49] and HCl [50–52]. These treatments help to change the surface area and incorporate functional groups that affect the adsorption capacity of the carbon.

5. Biochar derived biomass in Malaysia

The increasing energy demand in Malaysia illustrated in Fig. 1 shows a raise of around 0.4 quadrillion Btu in 1980 to 2.5 quadrillion Btu in 2006. The total energy consumption in Malaysia is predicted to boost by the year of 2020 together with various commercial industries taking place. Energy generation may benefit in adhering to the demand of the community to be used in many sectors [61] however the bad impact of the energy production is the high amount of CO_2 emitted during the power generation process as shown in Fig. 2. Thus it is important to generate greener energy solutions that emits low CO_2 but produces high energy and bio fuel.

Renewable energy was labeled as the fifth fuel in the Five Fuel Strategy of Malaysia's energy supply mix. In the eight Malaysia plan, it was foresee that the utilization of the abundant biomass will contribute to 5% of overall power requirement by 2005. Small Renewable Energy Power (SREP) Program was commenced in May 2001 which utilizes renewable resources involving generation of small power from plant with capacity not exceeding 10 MW [75]. The program started with the building of biomass power plant at a palm oil mill site which utilizes empty fruit bunches (EFB) as its main fuel and a landfill plant which uses landfill gas from the municipal storage waste sites. Other renewable resources that have been used are wood residues, rice husk, mini hydro and mix fuels. The program manages to produce a total of 375 MW energy with 325 MW connected back to the national distribution grid. EFB seems to show promising results for its abundance quantity as Malaysia is one of the top exporters of oil palm [76].

In efforts to reduce the GHG emissions, Biomass Power Generation and Demonstration (BioGen) Project was initiated in October 2002 by utilizing oil palm biomass residues and introduced biomass and biogas grid connected power generation project. The Malaysian government and the many private sectors in Malaysia were involved in this project. One of the BioGen project is in Tawau, Sabah which makes use of oil palm residues that has accomplished CO_2 sequestration for up to 40,000–50,000 t in 2004. FELDA Serting has also successfully generated 13 MW of energy at which 10 MW is being exported and 500 kW has been generated by FELDA Serting power plants in 2009. Other private palm oil mill has also successfully produced about 447 MW off-grid electricity [76].

Malaysia generates million tones of biomass each year and the various types of biomass have the potential to be used in many industrial activities. Oil palm is the major crop that contributes to the largest generation of biomass in Malaysia. In 2008, the total oil palm plantation in Malaysia has reached to the capacity of 4.49 million ha [65] and the number is expecting to increase tremendously by the year. This high gain industry is expected to produce almost 100 million dry tonnes of solid biomass by the year 2020. Currently the biomass is used as fertilizers, animal feed, bio-energy production and formed into pellets for the ease of transportation. By 2015, it is predicted the oil palm residues are to be used to produce bio fuels as petroleum substitute and bio based chemicals from its lignocellulosic materials which consist of hemicelluloses, cellulose and lignin [66].

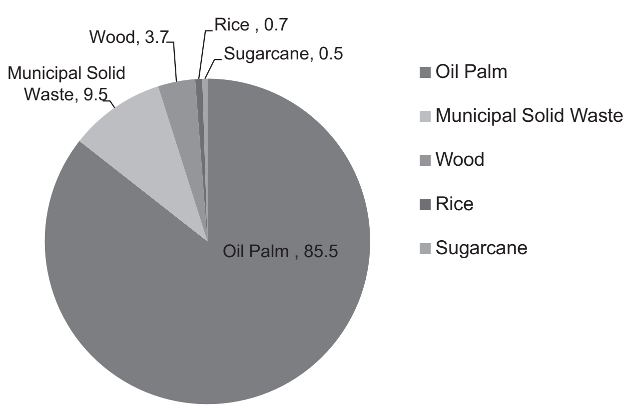

Fig. 3. Biomass residues produced from various industries in Malaysia [67].

Fig. 3 indicates that the oil palm is the major contributor to the biomass residues produced in Malaysia followed by municipal solid wastes as compared to other types of biomasses such as wood, rice and sugarcane. Many types of solid waste materials can be utilized from the palm oil extraction process such as the empty fruit bunch, shell, fiber, palm kernel, fronds and trunks as shown in Fig. 4. Sugarcane bagasse is also produced largely and is one of the major agriculture residues processed in Perlis, Malaysia [69]. Generally, 1 t of sugarcane generates 280 kg of bagasse which is the fibrous by product remained after sugar extraction [70]. Rice is one of the main crops produced largely in the world whereby almost 100 million tons of rice husks are produced yearly and 90% of the residues generated are from the emergent countries including Malaysia [71]. These agriculture residues are often used to feed farm animals in small quantities. However most are being discarded or burnt on land. For that reason it is beneficial for Malayian to make use of these resources to valuable use. The exploration of the potential utilization of this renewable energy is also highlighted in the 10th Malaysian Plan where the government encourages efforts to discover higher prospective of different biomass usage in various industries.

The abundant agricultural residues can be pyrolyzed to produce biochar. Biochar can be produced in a large reactor or by using a simple or small kiln as shown in Fig. 5. In Institute of Advanced Technology (ITMA) in University Putra Malaysia, biochar from various agricultural residues such as bamboo, wood and palm kernel are produced daily. The simple process consists of inserting agriculture residues inside the kiln and the brick enclosed space helps to hold and maintain high amount of heat, permitting fewer amount of biomass to perform the heat treatment. Installing temperature probes into the kiln will help to observe the temperature changes in the kiln [72]. The duration of

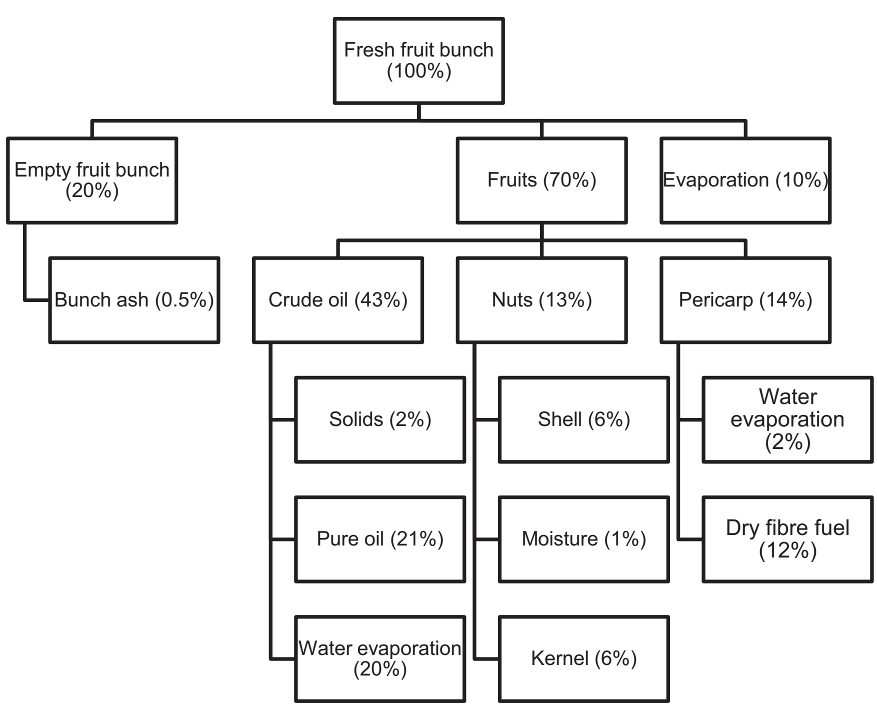

Fig. 4. Generation of products from oil mill production [68].

the pyrolysis depends highly on the moisture content in the biomass sample and may take a period of as short as 30 min to a few hours. Conversion of the biomass also depends on the biomass moisture content for example EFB which has 50% moisture content will result to 25% conversion by weight.

Fig. 5. A closed 200 kg steel barrel kiln in Institute of Advanced Technology (ITMA), University Putra Malaysia.

The production of biochar as carbon sink is recommended to be executed at the agricultural farm itself to reduce the transportation and laborer costs. Bio energy and biochar are produced from pyrolysis and the biochar is then applied to soil to increase the soil fertility, helps to revitalize degraded grounds and promotes carbon negative effects. Fig. 6 shows the utilization of biochar is preferred and beneficial in reducing CO_2 emission as compared to carbon neutral withdrawal by photosynthesis. The simple setup of kiln that can be constructed in the farm is beneficial as the system is not complicated and does not need high maintenance to be operated.

Biochar are also processed in order to reduce the volume and sizes of agriculture and industry wastes [74]. In Malaysia there are a few power plants that manage waste reduction for example Nasmech Technology that recover treatment technology in various fields and industries. The Green Technology mission is to promote effective techniques to generate energy and convert toxic to non-toxic products. Wastes such as industrial scheduled waste, medical hazardous waste, municipal and biomass waste are carbonized to form biochar. The operation has low CAPEX and OPEX and requires low maintenance. It is simple and can reduce the weight of waste to 75% to 98% [35]. Some of the agricultural wastes are pyrolyzed to form biochar. The biochar generated are ready to be used in many sectors such as agriculture and waste water industry. The capacity of biochar formed varies from 1 to 20 t of biochar depending on the types of biomass used as shown in Table 5.

Biochar can be produced in large volume per day by using reactors and the production is also achievable in small scale by constructing small kiln in the farmer's land to utilize the abundant agriculture residues in order to produce biochar. Therefore the biochar production is applicable in Malaysia and will be advantageous to many sectors and industries as it has the potential to generate energy, sequester carbon in soil and be commercially promoted to be used for CO_2 adsorption in the flue gas system.

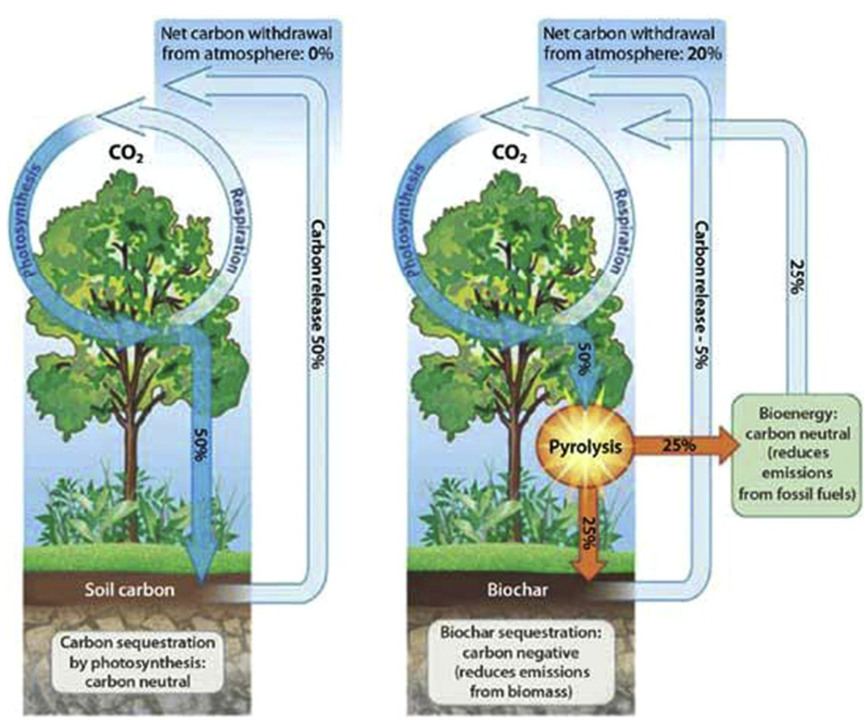

Fig. 6. Difference between carbon sequestration by photosynthesis and carbon negative approach [64].

Table 5
Nasmech technology's production capacity [73].

Capacity	Waste types	Project
8.0 t/Day carbonator^{TM}	Spent catalysts	2007
10.0 t/Day carbonator^{TM}	Biological sludge	2007
1.0 t/Day carbonator^{TM}	Chemical liquid	2007
1.0 t/Day carbonator^{TM}	Liquid solvent	2007
2.0 t/Day carbonator^{TM}	Metal hydroxide sludge and 1.0 t/Day liquid flux waste	2008
1.5 t/Day carbonator^{TM}	Mixed organic domestic	2008
8.0 t/Day carbonator^{TM}	Metal hydroxide sludge	2009
20.0 t/Day carbonator^{TM}	Oil palm EFB (Empty Fruit Bunch) waste	2009
1 t/Day carbonator^{TM}	Treating sort of liquid waste	2010
1.4 t/Day carbonator^{TM}	Treating biological sludge	2010
10 t/Day carbonator	Medical waste	2011
8 t/Day carbonator	Treating metal hydroxide	2011

6. Conclusion

Malaysia produces tonnes of agricultural wastes monthly and these wastes can be used to generate energy by producing bio oil and biochar. The utilization of biochar in soil application for enhancement of agriculture products is foresee to be beneficial as biochar has the ability to retain nutrients and high stability against decay. Biochar can be used to reduce the green house emission and applicable in the post combustion system to remove carbon dioxide. It is also produced to reduce the volume of waste. The waste water industry benefits in the usage of this porous structure carbon as it can be applied as dye sorbent in the textile industries. Further studies on the potential application of biochar are beneficial to further comprehend the mechanism and properties of the biochar.

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